CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-236
BARTLETT SPRINGS FAULT ZONE
LAKE AND MENDOCINO COUNTIES, CALIFORNIA

by
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Associate Geologist
December 9, 1993

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INTRODUCTION

Potentially active traces of the Bartlett Springs fault zone and related faults in the Bartlett Springs - Covelo study area are evaluated in this Fault Evaluation Report (FER) (Figure 1). Traces of the Bartlett Springs fault zone are located in the Clearlake Oaks, Lakeport, Lake Pillsbury, Potter Valley, Hull Mtn., Eden Valley, Laytonville, and Spyrock 15-minute quadrangles (Figure 1). Selected traces of the fault were mapped in more detail by this writer in the Potato Hill, Elk Mountain, Lake Pillsbury, NE1/4 Potter Valley (15′), Hull Mtn., and Sanhedrin Mtn. 7.5-minute quadrangles (Figure 1).

Traces of the Bartlett Springs and related faults in the Bartlett Springs - Covelo study area (including the Etsel Ridge and Updegraff Ridge faults) are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active (Holocene) and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (Hart, 1992).

SUMMARY OF AVAILABLE DATA

The Bartlett Springs - Covelo study area is located in the northcentral Coast Range geomorphic province. Deformation in the study area is dominated by the right-lateral strike-slip San Andreas fault system.

Rock types in the study area include Mesozoic Franciscan Complex (principally highly sheared melange) and Great Valley Sequence sedimentary rocks, Tertiary sedimentary rocks, and volcanic rocks principally of the late Pleistocene Clear Lake Volcanics (Etter, 1979; Jayko and others, 1989; McLaughlin and others, 1990; McNitt, 1969; Jordan, 1976). Late Quaternary alluvium generally is sparse throughout most of the Bartlett Springs - Covelo study area, being confined to pull apart basins such as the Lake Pillsbury area (Gravelly Valley) and Round Valley (Figures 2a-2d). Most of the late Quaternary alluvial deposits located on or near traces of the Bartlett Springs fault zone consist of very young stream alluvium and landslide debris.

Topography in the study area generally is mountainous with several intermontain valleys thought to be pull-apart basins related to strike-slip deformation (dePolo and others, 1984; Jayko and others, 1989; Etter, 1979). Elevations range from 365 m to 1220 m and the relief often is rugged. The rugged relief throughout much of the study area, combined with the generally unstable and incompetent nature of the bedrock, has resulted in often massive slope instability. Thus, landslide deposits commonly conceal or modify traces of the Bartlett Springs fault zone. The rate of erosion in the study area has not been quantified, but is inferred to be relatively high, no doubt exceeding the displacement rate of the Bartlett Springs fault zone. Therefore, geomorphic expression of recently active faults in the Bartlett Springs - Covelo study area may be quickly destroyed by erosional and mass wasting processes.

Aerial photographic interpretation by this writer of faults in the Bartlett Springs - Covelo study area was accomplished using aerial photographs from the U.S. Department of Agriculture (1952). Fault traces mapped by other workers were photo-checked for geomorphic evidence of Holocene activity and location accuracy. Annotations by this writer appear in black on Figures 2a-2d. Traces of the Bartlett Springs fault zone in the Lake Pillsbury area mapped by this writer were plotted directly on the aerial photographs and then transferred to 7.5-minute base maps using a Bausch and Lomb Zoom Transfer Scope.

Two days were spent in the field in mid-March 1993 by this writer, about half the anticipated time due to heavy rains in the study area and personal injury. Selected faults in the Lake Pillsbury area were field checked and subtle features not observable on aerial photographs were mapped. Results of aerial photographic interpretation and field observations by this writer are summarized on Figures 3a-3c.

LITERATURE REVIEW

The Bartlett Springs fault zone is a major northwest-trending, steeply dipping fault zone that has been reported from 1.5 km wide (McLaughlin, 1989; dePolo and Ohlin, 1984) to greater than 3 km wide (Etter, 1979). Compiled faults on Figures 2c and 2d form a zone up to 7 km wide. The fault can be traced for at least 120 km from east of the Clear Lake area northwest to the south side of Round Valley (Figure 1). North of Round Valley, Herd (1978) suggested that the Lake Mtn. fault zone may be the northern continuation of the Bartlett Springs fault zone. The Lake Mtn. fault is located north of the Bartlett Springs - Covelo study area and is not evaluated in this FER.

Workers have variously described the Bartlett Springs fault as a thrust fault related to the Coast Range Thrust (Bolt and Oakeshott, 1982), a right-normal oblique fault (McLaughlin and others, 1990), and a predominantly right-lateral strike-slip fault (dePolo and Ohlin, 1984; Dehlinger and Bolt, 1984; Clark, 1983; Geomatrix, 1986). Faults evaluated in this FER are considered to be characterized by predominantly right-lateral strike-slip displacement.

Cumulative right-lateral strike-slip displacement for the Bartlett Springs fault zone is not known. However, the juxtaposition of different rock units of the Franciscan Complex suggests a significant strike-slip component of displacement. Clark (1983) reported that a dike intruded into sedimentary rocks of unknown age is offset right-laterally 85 m. McLaughlin and others (1990) speculated that perhaps tens of kilometers of right-lateral strike-slip displacement has occurred along the fault. The maximum vertical offset could be greater than 1.5 km (down to SW) east of Clear Lake, based on estimates of the total thickness of the Plio-Pleistocene Cache Formation, whose depo-basin is structurally bounded on the northeast by the Bartlett Springs fault (McLaughlin and others, 1990).

Workers who have mapped all or parts of the fault zone include: CDWR (1966, 1969), McNitt (1968), Jordan (1978), Etter (1979), depolo and Ohlin (1984), Geomatrix (1986), McLaughlin and others (1990), and Jayko and others (1989) (Figures 2a-2d). Those workers that specifically addressed fault recency are limited to dePolo and Ohlin (1984), Geomatrix (1986), McLaughlin and others (1990), and Jayko and others (1989). Therefore, mapping by dePolo and Ohlin, Geomatrix, McLaughlin and others, and Jayko and others will be discussed in detail below.

dePolo and Ohlin (1984)

dePolo and Ohlin (1984) presented a poster at the 1984 Geological Society of America Annual Meeting in Reno, Nevada. The annotated strip maps for this poster presentation were never published, but a copy of the map and text presented at Reno were made available to this writer for evaluation. This map and text are cited in this FER as the published GSA abstract. dePolo and Ohlin mapped lineaments they considered to be late Quaternary active traces of the Bartlett Springs fault, based mainly on interpretation of aerial photographs with field checking in the Lake Pillsbury area only. They plotted lineaments on 1:62,500 scale base maps, but the only map available for this evaluation was at a scale of 1:100,000 with very little control. Therefore, those traces plotted in black on Figures 2a-2c should only be considered to be approximately located.

dePolo and Ohlin reported that the Bartlett Springs fault zone can be divided into four principal segments from north to south: the Elk Creek fault (after CDWR, 1969); the Hot Springs shear zone (after Etter, 1979); the Chalk Mountain segment; and the Wilson fault (after Lawton, 1956). They stated that the Bartlett Springs fault zone occupies a topographic low nearly coincident with a narrow belt of Franciscan melange and ultramafic rocks (Photo 1), is up to 1.5 km wide, and is steeply dipping.

dePolo and Ohlin stated that the Bartlett Springs fault zone is delineated by geomorphic features such as linear drainages, notches, benches, and depressions. They noted that a geomorphic analysis is difficult in the study area because: 1) geologic contacts also produce geomorphic expression; 2) the general lack of competence of the melange material; 3) generally northwest trending bedding and cleavage in bedrock units; 4) landslide related features; and 5) an older Tertiary history of displacement along the fault zone. They reported that geomorphic expression along the Elk Creek and Hot Springs segments seems to be more clearly tectonic in origin and includes swales and linear and closed depressions. However, the map used in the compilation for this FER was very lightly annotated. Specific annotations by dePolo and Ohlin are indicated in Figures 2a-2d by a boxed annotation.

Because dePolo and Ohlin did not identify offset deposits and because of the sparse annotations, most of the review of dePolo and Ohlin will consist of my photo checking of their fault traces. I annotated many of the traces with geomorphic evidence for the presence of faulting and locally where there was geomorphic evidence of recent strike-slip displacement (shown by un-boxed annotations on Figures 2a-2c). Those traces that I could verify are indicated with a red check mark on Figures 2b and 2c; those traces that I could not verify as having geomorphic evidence of recent strike-slip displacement are identified with an NV (Figures 2a-2c).

The southern-most faults shown in black on Figure 2a were compiled by dePolo and Ohlin based on preliminary mapping by McLaughlin and others (1990). Faults mapped by dePolo and Ohlin only generally correspond with traces mapped by McLaughlin and others (1990) southeast of Blodgett Canyon (locality 1, Figure 2a). Several traces are delineated by geomorphic features indicative of probable late Quaternary offset, such as linear and right-laterally deflected drainages (locally), troughs and linear ridges in bedrock, and occasional sidehill benches. However, detailed features and evidence of systematic strike-slip offset suggestive of latest Pleistocene or Holocene activity were not observed by this writer.

North of Blodgett Canyon dePolo and Ohlin mapped discontinuous lineaments generally delineated by large scale linear drainages, the large (5 km) right-lateral deflection of Bartlett Creek, saddles, and linear ridges (Figure 2a). However, geomorphic evidence of systematic latest Pleistocene to Holocene offset, such as systematically deflected drainages, shutter ridges, and closed depressions, was not observed by this writer.

dePolo and Ohlin mapped two discontinuous traces located near what Etter (1979) referred to as the Hot Springs shear zone (Figure 2b). Selected traces of the eastern branch mapped by dePolo and Ohlin were subsequently trenched by Geomatrix (1986) south of locality 9 (Figure 2b) and verified as Holocene active faults.

I did not verify traces mapped by dePolo and Ohlin south of the Rice Valley area along the eastern branch and I did not verify as recently active traces of the western branch (Figure 2b).

North of Lake Pillsbury dePolo and Ohlin identified Summit Lake as a sag pond (locality 2, Figure 2c). Traces mapped by dePolo and Ohlin from Lake Pillsbury northwest to the Dead Horse Canyon area (locality 3, Figure 2c) were generally verified by this writer as recently active.

An additional closed depression to the northwest of Summit Lake (locality 4, Figure 2c) was identified by dePolo and Ohlin. I confirmed the location of the closed depression, but there are no aligned linear geomorphic features indicative of active faulting on trend with the closed depression, suggesting that it may be related to gravitational processes.

Lineaments in the Elk Creek drainage area mapped by dePolo and Ohlin lack well defined geomorphic features indicative of latest Pleistocene to Holocene strike-slip displacement (Figure 2c). It is probable that erosion rates are equal to or greater than fault slip rates in this area. Nonetheless, the trend lacks well-defined geomorphic expression of faulting.

dePolo and Ohlin mapped three east-trending faults along the south side of Round Valley (Figure 2c). I was able to verify a south-facing scarp in bedrock at locality 5 (Figure 2c). However, this scarp is degraded and north-flowing drainages that cross the scarp do not reflect evidence of recent uplift. To the west this fault does not extend into the alluvium of Round Valley. The southern two east-trending faults were not verified (Figure 2c).

McLaughlin and Others, 1990

McLaughlin and others (1990) mapped traces of the Bartlett Springs fault in the southeastern quarter of the Clearlake Oaks 15-minute quadrangle (Little Indian Valley-Wilbur Springs geothermal area) (shown in red on Figure 2a). The Bartlett Springs fault offsets fluvial deposits of the Plio-Pleistocene Cache Formation within the mapped area of McLaughlin and others. These rocks are overlain by Pleistocene Clear Lake volcanics, which are also offset by the Bartlett Springs fault (dacite of Chalk Mountain). This volcanic unit may be as young as 0.7 my, based on normal polarity of the dacite (McLaughlin and others, 1990).

McLaughlin and others reported that the style of offset along the Bartlett Springs fault is normal (down to the west) with a locally prominent right-slip component. This style of offset is based on rake of slickensides, offsets, and truncations of rock units. Post-Blancan (early Pleistocene) vertical offsets of at least 2 m occur in Cache Formation rocks in the Benmore Canyon area (McLaughlin and others, 1990) (locality 6, Figure 2a). Slickensides along fault planes in this area show both vertical and lateral movement. Assuming that the 2 m vertical offset occurred about 1 ma, and that the horizontal component is 3 to 5 times the vertical, then 6 to 10 meters of right-slip has occurred, yielding a slip rate of 0.01mm/yr. If the horizontal component is 10 times the vertical, then a slip rate of 0.02mm/yr could be assumed. Cross-section B-B' of McLaughlin and others indicates that the base of the Plio-Pleistocene Cache Formation is vertically offset about 46 meters. Using the assumptions above for a 10 to 1 horizontal to vertical displacement, a slip rate of between 0.15mm/yr to 0.09mm/yr can be calculated, based on assumed ages for the Cache Formation of between $3x10^6$ and $5x10^6$ years, respectively.

Maximum (or cumulative) strike-slip displacement along the Bartlett Springs fault in the area mapped by McLaughlin is not known. However, the juxtaposition of different rock units of the Franciscan Complex suggests a significant strike-slip component of displacement. McLaughlin and others speculated that perhaps tens of kilometers of strike-slip displacement has occurred along the fault zone. Maximum vertical offset could be greater than 1.5 km (down to SW), based on estimates of the total thickness of the Plio-Pleistocene Cache Formation, whose depo-basin is structurally bounded on the northeast by the Bartlett Springs fault.

Significantly, McLaughlin and others stated that geomorphic features indicative of latest Pleistocene to Holocene activity, such as aligned sag ponds, have not been observed between the south end of Lake Pillsbury and McLaughlin and others' study area, and south of the map area to Lake Berryessa. Aerial photographic reconnaissance by this writer generally verified the location of traces of the Bartlett Springs fault mapped by McLaughlin and others, but those traces lacked ephemeral geomorphic features indicative of Holocene strike-slip or normal displacement (Figure 2a).

Geomatrix (1986)

Geomatrix (1986) mapped lineaments thought to be traces of the Bartlett Springs fault from east of the Clear Lake area northwest to Round Valley in order to assess the seismic hazard potential of the Bartlett Springs fault for the Scott Valley dam. This regional mapping was compiled at a very small scale (1:333,274) and is not plotted on Figures 2a-2c. Geomatrix plotted traces of the Bartlett Springs fault at a larger scale in the Lake Pillsbury area, shown in yellow on Figures 2b and 2c.

Geomatrix divided the Bartlett Springs fault zone into six discontinuous segments from the Wilson fault (southeast of the Bartlett Springs - Covelo study area) north to Round Valley and evaluated these segments based mainly on aerial photographic interpretation. From south to north the segments include: Chalk Mountain, Reister Rock, Twin Valley, McLeod Ridge, Coyote Rocks, and Elk Creek (Figures 1 and 2a-2c). Except for McLeod Ridge and Coyote Rocks segments, traces of the Bartlett Springs fault mapped by Geomatrix are not plotted on Figures 2a-2d. References to segments other than the McLeod Ridge and Coyote Rocks in this Geomatrix discussion apply to traces mapped by other workers.

The Chalk Mountain segment is about 24 km long and is delineated by well-defined offset ridges, aligned saddles, and some modified drainages. These features, according to Geomatrix, indicate limited Quaternary strike-slip offset (Figures 1 and 2a).

The Reister Rock segment is about 12 km long. Near Bartlett Springs the segment is characterized by a linear, deeply incised drainage with steep, unstable slopes (Figures 1 and 2a). Erosion and mass wasting have modified this segment to a significant degree. At the southern end of the segment discontinuous lineaments traverse a "strongly defined ridge line" without evidence of significant lateral displacement.

The Twin Valley segment is delineated by discontinuous photo lineaments, a conspicuous lineament along the northeastern alluvial margin of Twin Valley, and an apparent stepover across a topographic ridge (Figure 1). No geomorphic features suggestive of Quaternary fault displacement were observed by Geomatrix. Photo lineaments in hills were subdued and subparallel to regional structure.

The 16 km-long McLeod Ridge segment is characterized by west-northwest-trending, discontinuous lineaments subparallel to regional structure. Near the northern end of McLeod Ridge, small colluvial-filled basins were observed along discontinuous lineaments and, according to Geomatrix, may be either colluvium ponded against a fault, an eroded structure, or soil developed on less resistant rocks (locality 7, Figure 2b). At the northern end of the ridge an east-trending serpentine body crosses the fault (locality 8, Figures 2b and 3b) and is not offset within resolution of the aerial photography ($\pm$ 30m). However, I was able to verify a right-laterally offset vegetation contrast in this vicinity, based on air photo interpretation (locality 8, Figure 3b). As much as 90 m to 120 m of right-lateral offset is apparent.

Lake Pillsbury, which forms the boundary between the McLeod Ridge and Coyote Rocks segments, is probably a tectonic pull-apart basin (Figure 2b). Geomatrix reported that evidence for a pull apart basin includes: extensive Quaternary terrace and valley fill deposits within the basin and also on the western ridge; northeast-trending lineaments bordering the southern and northwestern margins of the basin that are spatially confined to the basin; location of the basin within a zone of strike-slip deformation; and orientation of the axis of the lake with respect to right-lateral displacement.

The 18 km-long Coyote Rocks segment contains geomorphic features and exposures that indicate late Quaternary and possible Holocene activity (Geomatrix, 1986). Two prominent lineaments identified by Geomatrix include the Coyote Rocks and Sunset Point lineaments (Figures 2b and 3b).

The Coyote Rocks lineament is delineated by a long topographic depression, 3 closed depressions, and linear vegetation contrasts (Figures 2b and 3b). Air photo interpretation by Geomatrix reported a closed depression just south of the runway north of Lake Pillsbury, a "photo lineament" just north of the runway, and a shear zone exposed in the stream bank at their Exposure A (locality 9, Figures 2b and 3b).

The Sunset Point lineament is delineated by a linear hill front, a well-defined scarp, and springs (Geomatrix, 1986) (Figures 2b and 3b). A natural stream cut across the fault exposed sheared and displaced alluvium (Exposure B, locality 10, Figures 2b and 3b). Trenching by Geomatrix confirmed Holocene offset (see trenching discussion below).

North of Lake Pillsbury the lineaments merge into a narrow linear trough (Figures 2b and 2c). Geomatrix reported that the trough has strong geomorphic expression of active faulting including disrupted drainages, truncated topography, and a closed depression.

The boundary between the Coyote Rocks and Elk Creek segments is delineated by a major E-W trending ridge and a 3 km left-step. Geomatrix reported that the Elk Creek segment is a poorly defined and wide, diffuse zone of lineaments (Figure 2c). They stated that this zone is the least well-defined segment delineating the Bartlett Springs fault zone. Round Valley has an east-trending lineament along its southern boundary (see dePolo and Ohlin (1984), Figure 2c), but Geomatrix did not find geomorphic evidence of faulting in the alluvium of Round Valley.

Geomatrix excavated 5 trenches and logged two stream cut exposures in the immediate vicinity of northern Lake Pillsbury (Figures 2b, 3b).

Trench T-1 is a 19.8 m (65 foot)-long excavation located just northwest of a closed depression and along a southwest-facing scarp in alluvium (Figures 2b and 3b). The trench was only excavated to a depth of 1.5 m (5 feet) because of shallow groundwater conditions. A gray gravel unit on the east side of the fault is warped down to the southwest and does not obviously continue to the west across the fault. The trench did not extend deep enough to expose direct evidence of faulting, but along the axis of the trough is a thick gravel and organic silt unit. The bottom of the unit is not exposed. This unit then thins to the southwest. It is assumed that the trough and the material filling the trough are the result of faulting rather than erosional/depositional processes. A black silt unit is the uppermost/youngest unit exposed on the northeast side of the trough. The undissected nature of the terrace and the lack of an apparent well-developed soil profile indicate a latest Pleistocene to Holocene age for the terrace surface.

Trench T-2 is a 15.2 m (50 foot)-long trench located 655 meters northwest of T-1 along the fault (and north of the runway at Gravelly Valley) (Figures 2b and 3b). The 2.1 m (7 foot) deep trench exposed poorly to moderately (?) bedded gravel units. A disturbed zone that coincides with a 3 m (10 foot) wide zone of caved trench is located beneath a vegetation contrast at the surface. There seems to be a truncation of gravel units on the northeast side of the inferred fault, based on the different stratigraphic sequence of gravels on the southwest as compared with the stratigraphic sequence on the northeast side of the fault. The uppermost, youngest unit (soil unit) is a silty gravel on the southwest side of the fault. The soil unit thickens across the fault and changes to a "silt/soil". This thickening is consistent with a down-to-the-east sense of vertical separation noted in exposures to the north. A "dry gravel" unit is exposed at the bottom of the trench and is lower stratigraphically on the southwest side of the inferred fault, suggesting offset along the fault. A 0.8m to 1m wide disturbed zone of massive gravelly sand coincides with the vegetation lineament at the surface.

Trench T-3 was cut across a 2 meter high scarp (Figures 2b, 3b, and 4). This 6 m (20 foot) long, 2.4 (8 foot) deep trench exposed bedrock on the southwest juxtaposed against colluvial deposits on the northeast (Figure 4). Serpentine gouge separates the two units. A gradational contact between a gravelly sand silt and an overlying clayey silt with gravel unit steepens at the fault, indicating drag associated with a up-on-the-southwest component of vertical offset. An approximately 15.2 cm (6 inch) thick soil (termed silt on log) does not thicken across the fault. Three radiocarbon samples were taken in the deformed gravelly sandy silt unit, indicating the age of the unit to be 3800 ybp (Figure 4). Geomatrix theorized that trench T-3 has evidence of at least three faulting events. The fault plane exposed in T-3 strikes N45°W an dips 65°NE and slickensides along the fault plunge 15°-17° to the southeast, indicating right-lateral oblique displacement. The fault plane is delineated by a 24-58 cm wide zone of intensely sheared serpentinite gouge that contains many planar shears with slickensides. Two colluvial units separated by a weak stoneline are interpreted by Geomatirx to be scarp-derived colluvial wedges. Soil-filled fissures are indicated in the trench log by "yellow clay" and "gravelly sand". Geomatrix postulated that the youngest fault rupture event occurred 300-1000 years ago, because the fault affects the modern soil (not clear on log of T-3 how fault affects modern soil).

T-4 is a 1.5 m (15 foot) long excavation along a natural exposure (Exposure A) near Coyote Rocks (locality 9, Figures 2b, 3b, and 5). The trench exposed steeply dipping oxidized, weathered clayey gravel. This unit is in fault contact with nearly horizontal unweathered silty gravel located on the northeast side of the fault. These two alluvial units are separated by about 1.7 m (5.5 feet) of clayey serpentinite gouge (Figure 5, Photo 2). The fault strikes N45°W, dips 65°NE, with slickensides that plunge 15° to the southeast. Geomatrix stated that the two alluvial units are separated by a subhorizontal depositional contact (not on log) and that this contact has been displaced (down to east) about 2 to 3 meters. Using this apparent vertical separation and the 15° plunge of slickensides, a 7 to 11 meter right-lateral component and net slip amount can be calculated. Thus, a slip rate of between 1 and 2 mm/yr is indicated, based on the 3800 ybp age of the oldest exposed alluvium.

A 33.5 m (110 foot) long exposure with up to 12.2 m (40 feet) of vertical exposure across the Sunset Point lineament was logged by Geomatrix (Exposure B, locality 10, Figures 2b, 3b, and 6). The stream-cut exposure crossed a southwest-facing scarp approximately 2.7m (9 feet) high and exposed faulted alluvial/colluvial deposits (Figure 6, Photo 3). A deeply oxidized red conglomerate is overlain by an un-oxidized grey conglomerate, which in turn is overlain by a silty conglomerate. All of these units are vertically offset about 9 feet, including a stoneline in the red conglomerate about 0.9 m (3 feet) below the grey conglomerate/red conglomerate contact. This indicates that displacement occurred after formation of the terrace surface. Geomatrix estimated this terrace surface to be late Wisconsin or younger (<30ka). The exposed fault zone is about 1-1.5 meters wide and consists of a disturbed zone slightly more clayey and with vertically oriented pebbles (Figure 6). Geomatrix stated that subtle inflections in the scarp-slope angle to the south of Exposure B indicate multiple events. If true, then all of these events must postdate formation of the terrace surface. Geomatrix was not able to ascertain the number of events or slip per event because of trench collapses south of Exposure B.

Geomatrix concluded that the Bartlett Springs fault is an immature zone of right-lateral shear related to evolution of the San Andreas fault system. They suggested that the zone probably began to develop as the Mendocino Triple Junction migrated northward past the approximate latitude of Lake Pillsbury about 4ma. They inferred, based on air photo interpretation, that the shear zone is composed of individual segments that have had varying fault histories. The segments have not matured into a through-going, single fault system. As the shear zone developed, strike-slip movement may have utilized pre-existing structures such as faults, dipping contacts, intrusive masses, and formational planes of weakness. Reactivation of the Coast Range Thrust, per se, or of other buried thrusts within the Coast Ranges was not supported by existing data according to Geomatrix.

Jayko and others (1989)

Jayko and others (1989) compiled mapping of others in addition to their own mapping at a scale of 1:100,000, shown in pink on Figures 2c and 2d. Not all faults on their maps are plotted on Figures 2c and 2d; only the faults reasonably on trend with the Bartlett Springs fault zone to the southeast are shown.

Jayko and others reported that two faults in the study area, the Round Valley and Etsel Ridge faults, are structures they consider to be active faults (activity not defined) and infer a relationship to the San Andreas fault system (Figures 2c and 2d). Evidence of activity was not presented, but was inferred based primarily on geomorphic expression, including linear ridges and drainages, notches, beheaded drainages, springs, and sag ponds.

<u>Round Valley Fault Zone (Elk Creek Segment of Geomatrix, 1986)</u>

Late Quaternary deposits along strands of the Round Valley fault zone are very sparse and generally consist of late Holocene stream alluvium and landslide debris (Jayko and others, 1989) (Figure 2c).

Thus, late Quaternary offset is difficult to demonstrate along much of this fault zone. Perhaps significantly, undifferentiated Quaternary alluvium in Round Valley is not shown to be offset along any of the northwest trending branches of the Round Valley fault (Figures 2c and 2d). Jayko and others do not show east-trending faults at the southern end of Round Valley as mapped by dePolo and Ohlin (1984) (Figure 2c).

I verified the southernmost part of the Round Valley fault in Figure 2c. This is the strand of the fault in the Summit Lake area that is delineated by a linear drainage and closed depression. North of locality 11 (Figure 2c) I did not verify recently active traces of the Round Valley fault as mapped by Jayko and others. Traces here are delineated by geomorphic features more characteristic of erosion along a fault zone (fault line features) than recent surface fault rupture. Specifically, traces lack systematically deflected drainages, sidehill benches, shutter ridges, and closed depressions (Figure 2c).

Etsel Ridge Fault

Jayko and others mapped traces of a northwest-trending fault they call the Etsel Ridge fault northeast of Round Valley (Figure 2d). The southeastern part of the fault in the Hull Valley area is concealed by undifferentiated Quaternary alluvium (locality 12, Figure 2d).

The northernmost strand of the Etsel Ridge fault is the southern-most strand of Herd's (1978) Lake Mtn. fault zone. This fault is delineated by closed depressions and linear sidehill troughs to the north of the study area (Herd, 1978). In the study area the fault is delineated locally by a closed depression and linear bedrock escarpment (locality 13, Figure 2d) and just north of the Spyrock qd boundary the fault is defined by a linear trough. However, farther southeast this fault is poorly defined and I could not verify latest Pleistocene to Holocene activity (Figure 2d).

I did not verify most of the Etsel Ridge fault as a late Quaternary active fault, based on reconnaissance aerial photographic interpretation. Specifically, the fault lacks right-laterally deflected drainages, sidehill benches, closed depressions, or linear troughs. Features that do delineate the fault are more suggestive of an erosional origin, such as broad troughs and linear drainages, saddles, benches (Figure 2d).

A northwest-trending fault mapped by Jayko and others west of the Etsel Ridge fault zone and east of the Updegraff Ridge fault locally is delineated by geomorphic features suggest of late Quaternary strike-slip displacement, such as right-laterally deflected drainages and linear drainages (locality 14, Figure 2d). Evidence of Holocene displacement is lacking and the features thought to delineate late Quaternary offset continue for only about 2.5km.

Updegraff Ridge Fault

Jayko and others mapped an unnamed, northwest-trending, presumably right-lateral strike-slip fault along Updegraff Ridge (Figure 2d). This fault is informally referred to in this FER and the Updegraff Ridge fault. The fault offsets units of the Franciscan Assembly, but there is a lack of late Quaternary stratigraphy across the fault. The southeastern end of this fault as mapped by Jayko and others does not extend into and offset alluvial deposits in Round Valley (locality 15, Figure 2d).

The fault is mostly obscured by massive landslides in the Updegraff Ridge area. Strands of the Updegraff Ridge fault are poorly defined and lack geomorphic evidence of recent strike-slip faulting, based on my air photo interpretation (Figure 2d).

McNitt (1968)

McNitt mapped traces of the southern Bartlett Springs fault in the Clearlake Oaks 15′ quadrangle (Figure 2a). McNitt mapped broadly arcuate, generally southwest-dipping faults that locally offset deposits of the Plio-Pleistocene Cache Formation (Figure 2a). Traces mapped by McNitt generally are located east of the faults mapped by McLaughlin and others (1990) and dePolo and Ohlin (1984) south of the Blodgett Canyon area (locality 1, Figure 2a). North of locality 1, mapping by McNitt crudely corresponds with mapping by dePolo and Ohlin, although significant differences in detail exist (Figure 2a). I did not verify traces of the Bartlett Springs fault mapped by McNitt as recently active, based on air photo interpretation.

McNitt mapped a north trending fault west of the Bartlett Springs fault in the southern half of the Clearlake Oaks quadrangle (Fault A on Figure 2a). This fault is probably an east-dipping normal fault that offsets deposits of the Plio-Pleistocene Cache Formation. Late Quaternary fluvial terraces are not offset by this fault (locality 30) and it is not delineated by geomorphic evidence of recent normal faulting, based on air photo interpretation by this writer (Figure 2a).

Etter (1979)

Etter (1979) mapped traces of a northwest-trending shear zone in the Lake Pillsbury 15-minute quadrangle he referred to as the Hot Springs shear zone (Figure 2b). The Hot Springs shear zone is similar to the Elk Creek segment of Geomatrix (1986) and the Round Valley fault of Jayko and others (1989) (Figure 2b). This shear zone, according to Etter, is a poorly defined northwest-trending zone up to 3 km wide consisting of complex structure and uncertain stratigraphy. The shear zone, a distinct topographic low, is characterized by thermal, mineral and carbonated springs, and hydrothermally altered rock. In addition, linear serpentinite bodies occur in the shear zone, especially bordering the southwestern part of the zone. The northeastern boundary of the zone is poorly defined and its position northwest of the Rice Valley area is generally inferred.

Etter considered the Hot Springs shear zone to be a near vertical strike-slip fault zone, based on the linearity of the shear zone, the near vertical dips of stratigraphic units within the shear zone, the apparent depth of the shear zone that would be sufficient to tap thermal energy at an unknown depth. The deflected topography and axial traces of folds bordering the shear zone indicate right-lateral strike-slip displacement. The amount of displacement is not known.

Etter mapped bedrock units offset by the Hot Springs shear zone, but does not map Quaternary units offset by the fault. Traces of the Hot Springs shear zone locally correspond to traces of the Bartlett Springs fault mapped by dePolo and Ohlin (1984) and Geomatrix (1986), although most of his traces do not correspond to mapping by others.

I did not verify as recently active most of the Hot Springs shear zone as mapped by Etter. The best defined section of the Bartlett Springs fault zone, located at Gravelly Valley just north of Lake Pillsbury, was not mapped by Etter (Figure 2b). Most traces are generally delineated by geomorphic evidence indicative of erosion along a fault, such as linear drainages, benches, linear ridges, and tonal lineaments in bedrock (Figure 2b). Geomorphic evidence of latest Pleistocene to Holocene strike-slip offset was not observed.

Jordan (1978)

A northwest-trending fault mapped by Jordan (1978) is shown in orange in the Eden Valley 15′ quadrangle (Figure 2c). Jordan, who mapped at a scale of 1:62,500 scale, suspected that strike-slip faulting may exist in his study area, and indicated right-lateral strike-slip displacement in cross sections A-A′ and B-B′. He also speculated that the formation of Round Valley, and other small basins in his study area, was due to strike-slip deformation along right-stepping fault segments. However, the magnitude of right-lateral offset is not known.

The northwest-trending fault crosses two Quaternary deposits mapped by Jordan (Figure 2c). Alluvium of probable Holocene age near the Elk Creek Ranch is mapped as concealing the fault (locality 16, Figure 2c). The northern end of the fault in Jordan's study area is concealed by alluvial deposits of possible Plio-Pleistocene age.

Jordan's mapping only locally corresponds with mapping by dePolo and Ohlin (1984), Jayko and others (1989), and CDWR (1969) (Figure 2c). The area around Summit Lake has reasonably good agreement with respect to fault location between dePolo and Ohlin, Geomatrix, Jayko and others, and CDWR (1969). The fault mapped by Jordan, however, is located from 200 m to greater than 600 m west of traces mapped by the other workers (Figure 2c).

Significantly, the area around Summit Lake is moderately well-defined, as demonstrated by the mapping of others and my own air photo interpretation (locality 2, Figures 2c and 3c). Thus it is concluded that the fault mapped by Jordan is very generalized and should not be considered accurate enough for evaluation. This is confirmed by my reconnaissance air photo interpretation which did not verify the majority of the fault trace mapped by Jordan.

CDWR (1969)

CDWR (1969) mapped traces of the Bartlett Springs fault zone (shown in grey on Figure 2c). Mapping was generally concentrated on the bedrock geology rather than on the late Quaternary geology of the region. None of the faults mapped are depicted as offsetting alluvial deposits, which are very sparse in the mapped area. The majority of the faults mapped by CDWR (1969) are steeply dipping to vertical, based on their cross sections. The fault in the Summit Lake area generally corresponds to the mapping of others and my air photo interpretation (Figure 2c).

Northwest of the Summit Lake area traces mapped by CDWR (1969) in the Elk Creek drainage area are delineated by geomorphic features suggestive of Quaternary displacement, but lack evidence of latest Pleistocene to Holocene offset (Figure 2c). Faults on the western and eastern margins of the Bartlett Springs fault were not evaluated by this writer.

CDWR (1966)

CDWR (1966) mapped a portion of the NW 1/4 of the Eden Valley and a small portion of the Laytonville 15′ quadrangles (scale of 1:24,000) for a tunnel alignment study for the Upper Eel River development (shown in purple on Figure 2c). At locality 17 (Figure 2c). CDWR (1966) mapped two faults as extending into young alluvium. However, the northwest-trending fault at locality 17 is also shown on their tunnel alignment cross section and does not extend into the alluvium. The northeast-trending fault also extends for only about 100-150 meters into the alluvium of Round Valley. It is probable that this is a drafting error or oversight because I did not verify the location of the fault in the alluvium and because of the extremely short distance into the alluvium the fault is projected (the distance of one dashed line).

Additional northwest-trending faults mapped by CDWR (1966) in the northeastern-most corner of the Laytonville 15′ quadrangle were not verified by this writer, based on air photo reconnaissance (Figure 2c).

AERIAL PHOTOGRAPHIC INTERPRETATION AND FIELD INSPECTION

Aerial photographic interpretation by this writer was done primarily to verify the location and activity of traces mapped by other workers (Figures 2a to 2d). Those traces verified with respect to location and activity are indicated by a red check mark. Those traces not verified with respect to activity or location are indicated by NV. Most of the Bartlett Springs fault zone is moderately to poorly defined and lacks geomorphic evidence of latest Pleistocene to Holocene right-lateral strike-slip or vertical offset (Figures 2a-2d). The exception is in the Lake Pillsbury area (Figures 3a-3c). Figures 3a-3c depict the interpretation by this writer of recently active faults in the Potato Hill, Elk Mountain, Lake Pillsbury, NE1/4 Potter Valley 15-minute, Hull Mtn., and Sanhedrin Mtn. 7.5-minute quadrangles.

Lake Pillsbury Area

The most convincing geomorphic evidence of latest Pleistocene to Holocene strike-slip displacement is located just north of Lake Pillsbury in the Gravelly Valley area (Figure 3b). A well-defined linear vegetation contrast in alluvium, linear shoreline (scarp), closed depression, and linear trough in alluvium were observed near locality 18 (Figure 3b), based on air photo interpretation and field inspection. Geomatrix (1986) trenched these lineaments and confirmed the presence of faulting. Radiometric age dates of offset soils exposed in trench T-3 (Figures 3b and 5) demonstrate Holocene offset. Also, the mapping by Geomatrix is generally consistent with my air photo interpretation in the Gravelly Valley area, although differences in detail exist, especially northwest of Gravelly Valley (Figures 2b and 3b). Traces mapped by dePolo and Ohlin (1984) and Geomatrix (1986) north of Scott Dam were partly verified with respect to location, but these lineaments lack continuity and geomorphic features indicative of latest Pleistocene to Holocene offset (Figures 2b and 3b).

That Gravelly Valley is a pull-apart basin is supported by a normal oblique fault located on the east side of the basin (Sunset Point lineament of Geomatrix) (Figure 3b). This fault is delineated by a west-facing scarp up to 10 meters high that cuts alluvial deposits (localities 10 and 19, Figures 2b, 3b; Photo 3). Geomatrix (1986) trenched this fault and found evidence of Holocene activity (also, see description for Exposure B).

Traces of the Coyote Rocks and Sunset Point lineaments merge north of Gravelly Valley (Figure 3b). Principal active traces of the Bartlett Spring fault north of Gravelly Valley are less well-defined and are delineated by geomorphic features such as linear drainages, linear and truncated ridges, troughs, occasional sidehill benches and right-laterally deflected drainages, and a closed depression (Summit Lake) (i.e., localities 2, 20-22, Figures 3b and 3c).

North of Sportsman Creek (locality 23, Figure 3c) the fault is moderately defined by a broad sidehill trough. North of Springs Creek the fault is concealed by massive landslide deposits and cannot be followed as an active strike-slip fault northwest to the northern border of the Bartlett Springs - Covelo study area (Figures 2b-2d).

South of Lake Pillsbury

South of Gravelly Valley the Bartlett Springs fault is delineated by a broad zone of discontinuous, distributive strands (Figures 3a and 3b). The best defined traces occur in the McLeod Ridge area and are delineated by linear ridges and troughs, truncated ridges, ponded alluvium, and occasional right-laterally deflected drainages (i.e., localities 24-28, Figures 3a and 3b).

The fault is much less well-defined southeast of Bear Creek and could not be followed to the southeast as an active fault (locality 29, Figure 3a).

SEISMICITY

The Bartlett Springs fault zone in and southeast of the Lake Pillsbury area is defined by a zone of microseismicity as depicted in Figure 7 (CIT, 1985). Dehlinger and Bolt (1984) reported that focal plane solutions indicate that earthquakes are predominantly right-lateral strike-slip. Earthquake epicenters generally are located 2 km to 3 km northeast of the Bartlett Springs fault zone, suggesting that either the fault dips steeply to the northeast or that location errors due to velocity modeling occur.

CONCLUSIONS

The Bartlett Springs fault zone is at least 120 km long and extends from east of Clear Lake northwest to Round Valley (Figures 1, 2a-2d). The fault zone probably continues to the northwest in a distributive manner and may complexly connect with Herd's (1978) Lake Mtn. fault. However, the Lake Mtn. fault was not evaluated in this FER.

Workers have variously described the Bartlett Springs fault as a thrust fault related to the Coast Range Thrust (Bolt and Oakeshott, 1982), a right-normal oblique fault (McLaughlin and others, 1990), and a predominantly right-lateral strike-slip fault (dePolo and Ohlin, 1984; Dehlinger and Bolt, 1984; Clark, 1983; Geomatrix, 1986). Most of the faults evaluated in this FER are characterized by right-lateral strike-slip or right-normal oblique displacement. Significantly, much of the study area is underlain by highly sheared, incompetent melange of the Franciscan Complex. Erosion rates in the study area are probably high and pervasive mass wasting and lateral spreading of ridges is common. Thus, identification of fault produced geomorphic features is very difficult in this terrain and it is conceivable that Holocene strike-slip faulting on the order of about 1mm/yr would not be preserved.

Cumulative right-lateral strike-slip displacement is not known for the Bartlett Springs fault. Clark (1983) reported that a mafic dike that intruded sedimentary rocks of unknown age was right-laterally offset 85 m. McLaughlin and others (1990) speculated that perhaps tens of kilometers of strike-slip displacement has occurred along the fault. The maximum vertical offset could be greater than 1.5 km (down to SW) east of Clear Lake. Regardless, the juxtaposition of different rock units of the Franciscan Complex suggests a significant strike-slip component of displacement.

Geomatrix (1986) divided the Bartlett Springs fault south of Round Valley into six segments, from south to north the Chalk Mountain, Reister Rock, Twin Valley, McLeod Ridge, Coyote Rocks, and Elk Creek segments (Figures 1, 2a-2d). The Coyote Rocks and McLeod segments are the only segments that are delineated by geomorphic evidence of Holocene right-lateral strike-slip displacement, based on investigations by Geomatrix (1986) and air photo interpretation by this writer (Figures 2b and 3a-3c). Well-documented Holocene active traces of the Bartlett Springs fault are located in Gravelly Valley just north and east of Lake Pillsbury (Figures 2b and 3b). Evidence for Holocene activity includes well-defined geomorphic features such as closed depressions, linear vegetation contrasts and linear troughs in Holocene alluvium (fluvial terraces), scarps in late Pleistocene terraces, and faulted Holocene colluvial deposits exposed in trenches excavated by Geomatrix (1986) (i.e. localities 2, 9, 10, 18, 19, Figures 3b, 4-6). The McLeod Ridge segment of the Bartlett Springs fault zone south of Lake Pillsbury is delineated by geomorphic features indicative of Holocene strike-slip displacement such as right-laterally deflected drainages, sidehill benches, sharp troughs and scarps, ponded alluvium, and truncated ridges (localities 25-29, Figures 3a and 3b). Geomorphic expression of this fault zone, however, is locally obscured by landslides and lateral spreading of ridges.

Geomatrix (1986) inferred a Holocene slip rate of between 1 and 2 mm/yr for the Coyote Rocks segment of the Bartlett Springs fault zone, based on trench exposures and radiometrically dated deposits. The amount of offset is inferred from apparent vertical separation of offset deposits and the plunge of striations on the fault plane.

Traces of the Bartlett Springs fault both southeast and northwest of the Coyote Rocks and McLeod Ridge segments are delineated by geomorphic evidence suggestive of discontinuous and distributive late Quaternary strike-slip displacement, but traces lack systematic evidence of Holocene strike-slip offset (Figures 2a-2d). It is possible, however, that Holocene displacement has occurred on other strands of the Bartlett Springs fault, but is poorly defined. This is in part due to the relatively high rates of erosion that are assumed to occur in the Bartlett Springs - Covelo study area and the generally highly sheared and incompetent nature of the bedrock in the study area.

From Round Valley north to latitude 40° traces of the Bartlett Springs fault zone include the Round Valley, Etsel Ridge, and Updegraff Ridge faults (Figures 2c and 2d). The Etsel Ridge fault crosses and does not offset late Quaternary alluvium at locality 12 (Figure 2d). The fault generally is poorly defined and lacks geomorphic evidence of Holocene active faulting. The northern-most part of the fault may connect with Herd's (1978) Lake Mtn. fault north of the Bartlett Springs - Covelo study area. At locality 13 (Figure 2d) this trace is delineated by a scarp in bedrock, linear ridge, and a closed depression. These features may delineate a large landslide complex that has failed toward the Eel River drainage. To the southeast the fault lacks well-defined geomorphic evidence of Holocene strike-slip offset and to the northwest I lack photo coverage of Herd's Lake Mtn. fault.

The Round Valley fault, named by Jayko and others (1989), is the northern part of the Bartlett Springs fault and is part of the Elk Mountain segment of Geomatrix (1986) (Figures 1 and 2c). This fault is poorly defined and lacks geomorphic features indicative of Holocene displacement.

The Updegraff Ridge fault was mapped by Jayko and others along the east side of Updegraff Ridge (Figure 2d). The fault is mostly concealed by massive landslide deposits and, except for a short strand at locality 14 (Figure 2d) is poorly defined and lacks geomorphic evidence of Holocene strike-slip offset. The fault trace at locality 14, delineated by a crude linear trough and two right-laterally deflected drainages, is suggestive of latest Pleistocene offset, but lacks geomorphic evidence of systematic Holocene strike-slip displacement, is only moderately defined, and is not delineated by youthful geomorphic features northwest and southeast of this locality.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1992).

Zone for special studies well-defined traces of the Bartlett Springs fault zone as shown on Figures 3a-3c. Principal references cited should be Geomatrix (1986) and Bryant (this report).

Do not zone for special studies traces of the Bartlett Springs fault zone northwest of and southeast of the Lake Pillsbury area. These faults are neither sufficiently active nor well-defined.

Reviewed; recommendations approved.
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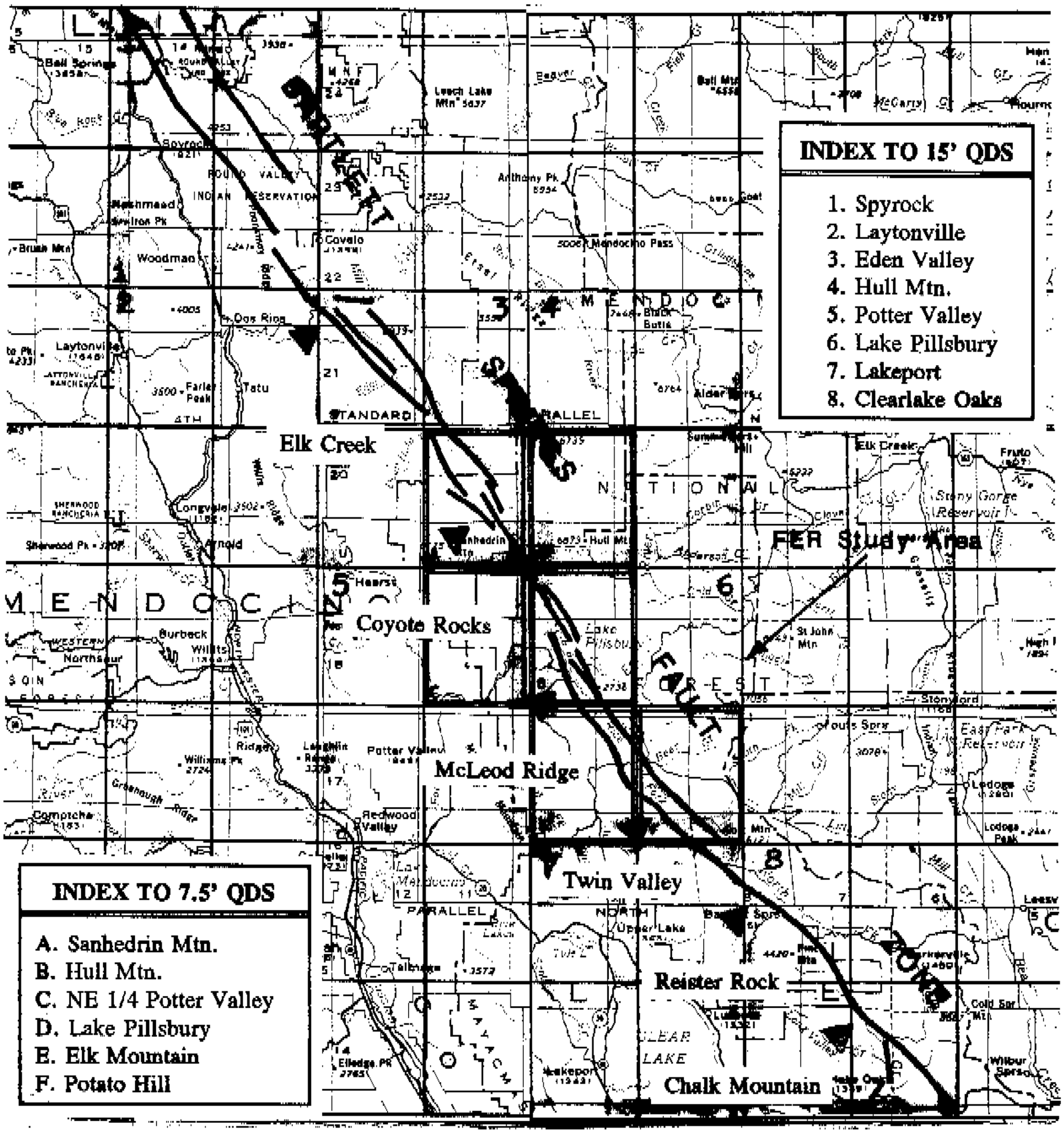

Figure 1 (to FER-236). Generalized location of faults in the Bartlett Springs - Covelo study area. Endpoints of segments of Bartlett Springs fault interpreted by Geomatrix (1986) are indicated by red triangles. Base map from USGS Index to Topographic and other Map Coverage (California), scale 1:682,500.

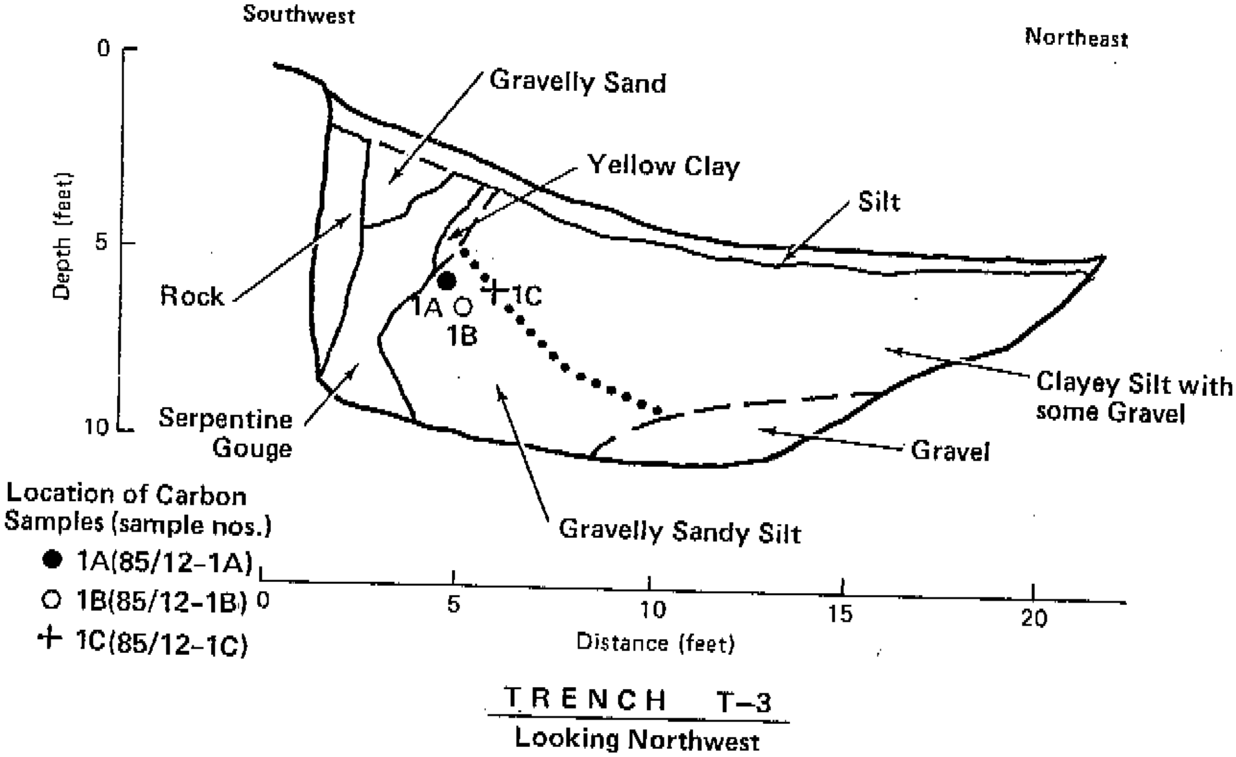

Figure 4 (to FER-236). Log of trench T-3 excavated by Geomatrix (1986). Refer to Figures 2b and 3b for location of exposure.

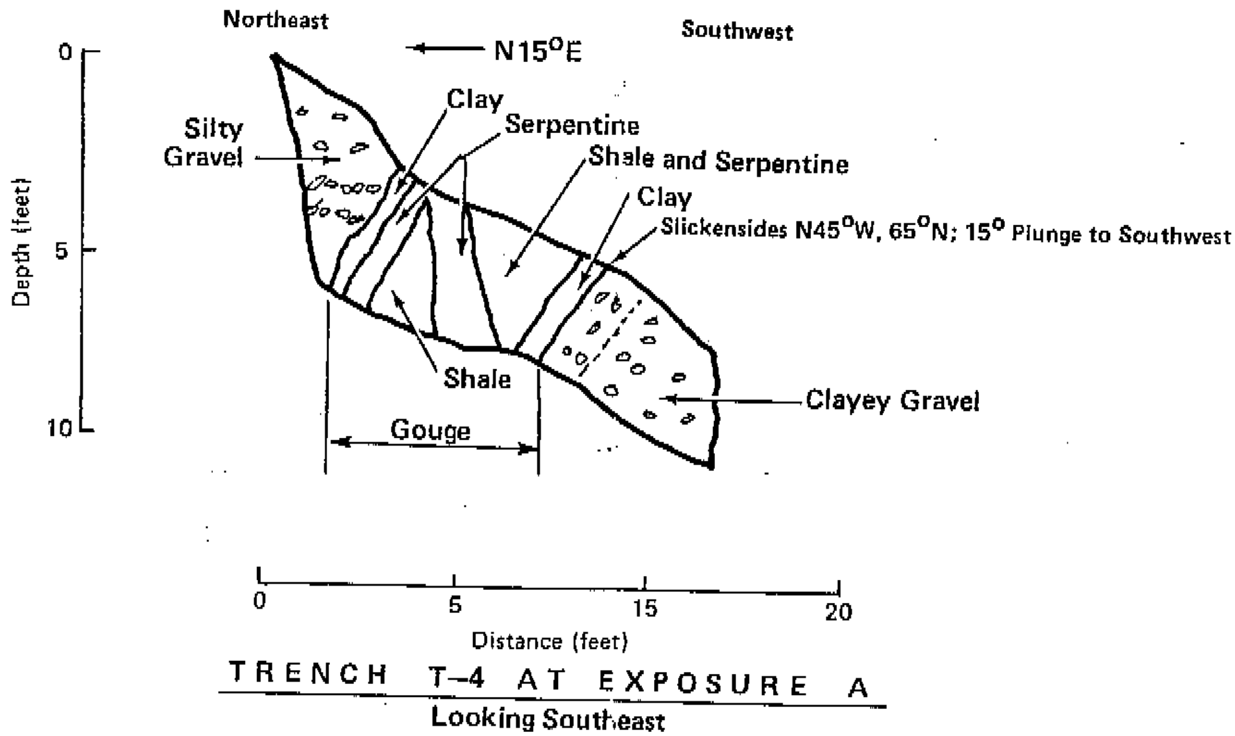

Figure 5 (to FER-236). Log of trench T-4 excavated by Geomatrix (1986). Photo 2 is near this location. Refer to Figures 2b and 3b for location of exposure.

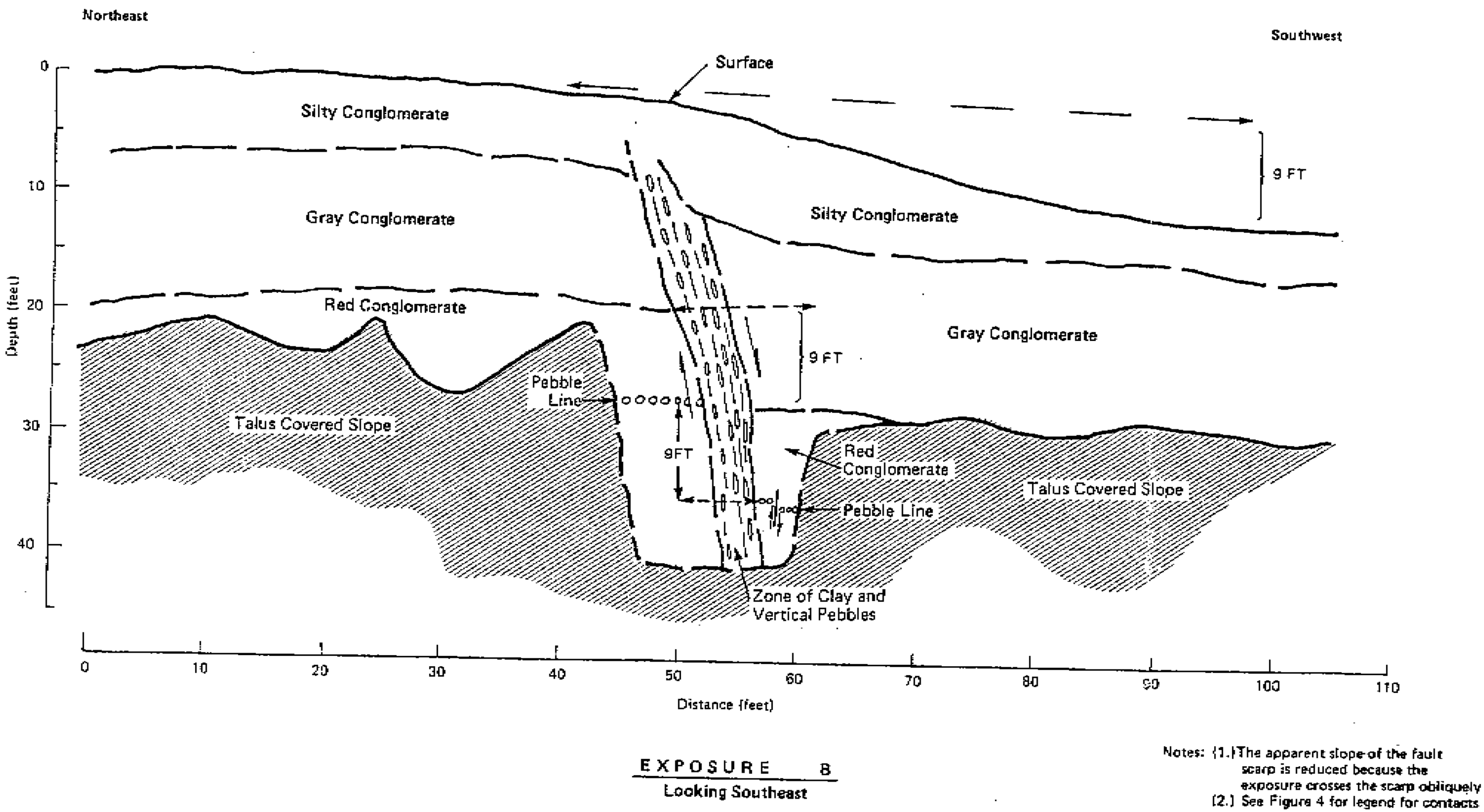

Figure 6 (to FER-236). Log of Exposure B cleaned and logged by Geomatrix (1986). Photo 3 is at this location. Refer to Figures 2b and 3b for location of exposure.

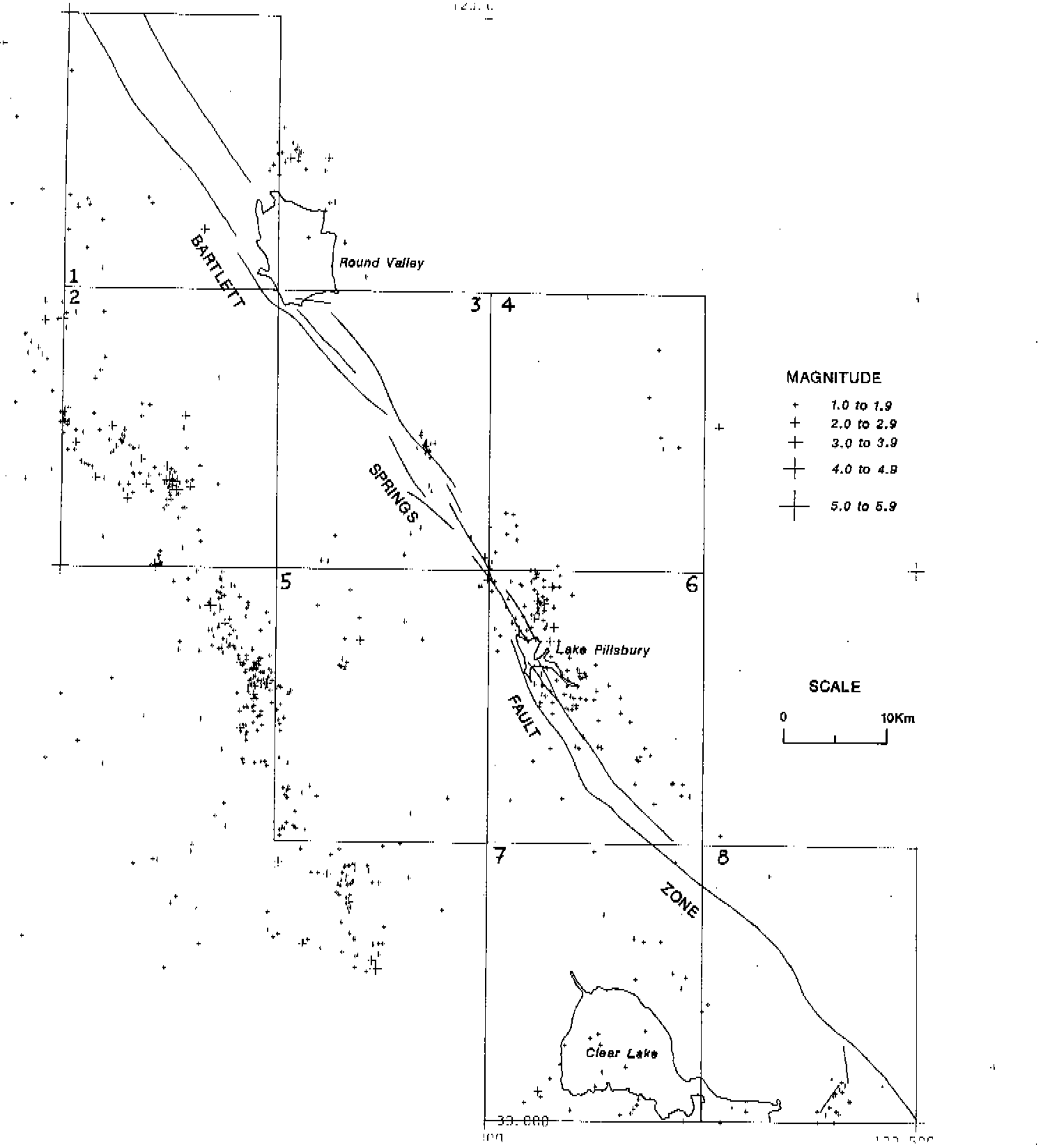

Figure 7 (to FER-236). Seismicity in the Bartlett Springs - Covelo study area, based on epicenter locations from CIT (1985). Seismicity west of the Bartlett Springs fault is associated with the Maacama fault. Refer to Figure 1 for index to 15-minute quadrangles.

Photo 1 (to FER-236). The Bartlett Springs fault zone characteristically is located in a topographically low region generally coincident with a northwest-trending zone of Franciscan melange. This view to the northwest illustrates the location of the Coyote Rocks segment of the Bartlett Springs fault (arrow) in the Gravelly Flat area just north of Lake Pillsbury (refer to locality 18, Figure 3b).

Photo 2 (to FER-236). View to the southeast of the Sunset Point lineament (Exposure B of Geomatrix, 1986). Late Pleistocene terrace deposits are vertically offset about 2.7 meters. The fault (arrow) is delineated by a disturbed zone of gravel with vertically oriented clasts. The southwest-facing scarp at this location is about 2.7 meters high. Refer to Figures 3b and 6 for location and log of Exposure B.

Photo 3 (to FER-236). Exposure of Coyote Rocks segment of Bartlett Springs fault near Exposure A of Geomatrix (1986). Fault offsets late Pleistocene terrace gravel against Holocene terrace deposits. Fault zone is delineated by serpentinite gouge (hammer).